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(54) Transform coding using coefficient prediction techniques

Transformationscodierung mit Koeffizientprädiktionstechniken

Codage par transformation utilisant des techniques de prédiction de coefficients

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Description

The present invention relates to a method and an apparatus for recovering a representation of an input image.

Especially, the invention relates to electronic image handling and more particularly to a system and method for operating on image data that has been transform coded e.g., motion video data, using coefficient prediction techniques, to optimally recover the coded image while facilitating efficient compression of the video data.

Efficient motion video compression systems typically use a combination of intraframe and interframe coding techniques. In intraframe coding a video frame (or field) of a sequence is coded without reference to any other frame (or field) in the video sequence. In interframe coding a video frame is coded by referencing one adjacent, previously coded frame. Since the typical information content of consecutive video frames changes very little, compression of frame differences, and thus interframe coding, is typically more efficient than intraframe coding. Efficiency can be further improved by applying well-known frame to frame motion compensation techniques to the basic interframe coding, as described for instance by H. MUSSMANN, P. PIRSCH, and H. GRALLETT, in "Advances in Picture Coding", Proc. IEEE, 73, 523, 1985. It is thus desirable to use interframe coding as much as possible to optimize compression rate in video sequences, but, nevertheless, intraframe coding cannot be avoided.

Intraframe coding is particularly necessary to handle scene changes and also to meet certain proposed requirements arising from recent standards efforts for motion video compression. Regarding these standards requirements, it appears that if certain proposals are adopted, it will be necessary to be able to access any video frame in a sequence within certain time limits, and to be able to playback a prerecorded video sequence in fast forward and fast reverse by accessing and skipping frames with a certain periodicity. Such requirements call for at least the periodic use of intraframe coding. For example, a fast forward mode at 10 times the normal speed would require accessing, decompressing, and displaying a video frame every 10 frames in the sequence. Since interframe coded frames need to refer to adjacent, previously decoded frames, they cannot be used to implement this function. Only intraframe coded frames can be decoded independently of others and thus a fast forward function at 10 times the normal speed requires an intraframe coded frame for every 10 frames. It follows that the length of time required to randomly access any frame in the video sequence will be constrained by the maximum number of frames between intraframe breaks. Unfortunately, the frequent recurrence of intraframe breaks degrades the quality of the image sequence that would be otherwise achievable. Intraframe transform coded frames, in particular, can show very annoying blocking artifacts at low bit rates. These

artifacts are particularly noticeable in smooth areas of the image and they appear as a periodic flashing of blocks which the interframe coding then gradually tends to correct.

- 5 Referring to the commonly-applied transform coding technique, it can be adapted for use with either the intraframe or interframe mode. In transform coding, particularly Discrete Cosine Transform Coding (DCT), an image is typically subdivided into blocks of, e.g., 8x8 pixels, each of which is then transformed through mathematical operations into a new representation of the original block of pixels. The "pixels" in the transformed blocks are called transform components or coefficients. Known examples of transform operations are the DCT, Haar, Hadamard, and lapped overlap transforms. In all cases, the transform operation has the property of compacting the energy of the original pixel blocks into a few transform components, such that only those coefficients need to be quantized, compressed, and transmitted.
- 10 When the transform components are quantized coarsely, which is the case with high compression rates typical of motion video standards, this block structure introduces "blocking" artifacts.
- 15 A technique is described by B. NISS in "Prediction of AC coefficients from the DC values", ISO/TC97/SC2/WG8 N745, May 1988, and "Prediction of AC coefficients from the DC values revisited", JPEG 147, ISO/TC97/SC2/WG8 document, June 1988, for improving the quality of a still frame that is coded using a progressive transmission DCT technique. Two versions of progressive still frame DCT encoders according to NISS's proposal are shown in Figs. 1a and 1b, along with a decoder in Fig. 2, which Figures are taken from, MITCHELL, J., B. NISS, W. PENNEBAKER, H.
- 20 FOULSEN, J. VAABEN, "Report on Front-End meeting", JPEG 245, ISO/IEC JTC1/SC2/WG8 document, Jan 23, 1989. As seen in Figs. 1a and 1b, an input representing a block of pixels from an original or other image to be coded is firstly transformed by DCT in a transformer 10. The DCT transform of the block of pixels produces a so-called DC-coefficient signal DC and a number of AC-coefficient signals AC. The DC coefficient is representative of the average value in the original block of pixels, while the AC-coefficients represent various harmonic frequencies therein. Initially, only the DC components are quantized Q in a quantizer 20 and transmitted over line 15. Also, using the quantized DC values only, some of the AC-coefficients can be estimated or predicted in an AC predictor 30. In the prior art technique of NISS the DC values of a set of 3x3 blocks are used in predicting AC-coefficients for the center block of the 3x3 array of blocks. With those predicted AC-values, the technique was able to improve the appearance of the image compared to that generated by the DC-components alone. In NISS's progressive transmission system the difference between the quantized original AC components on line 16 and their corresponding predictions, which are quantized Q in a quantizer 21,

is computed in a summer 40 and transmitted to obtain a coded version of the original image, as shown in Figure 1a. Alternatively, as seen in Figure 1b, the difference between the unquantized original AC components on line 16a and their corresponding predictions from the DC components may first be computed in summer 40 and then quantized Q in a quantizer 22 before being transmitted to obtain the coded image.

A typical decoder for use with the encoder of Fig. 1a is shown in Fig. 2. The coded and compressed signal received from the encoding transmitter is firstly decompressed and then processed as follows. The DC component is sent over line 17 to be dequantized Q^{-1} by dequantizer 25 and inverse transformed IDCT by inverse transformer 11, and also over line 18 to AC Predictor 31. The output of AC Predictor 31 is quantized Q by quantizer 23 and summed in a summer 41 with the corresponding AC coefficients from the received signal on line 19. The output of summer 41 is dequantized Q^{-1} by dequantizer 25 and inverse transformed IDCT by inverse transformer 11, and included in the decoded output with the decoded DC component.

It is important to note that in NISS's system AC-prediction is performed over the whole image regardless of whether the image contains smooth or active/complex areas. It also has no limitation on the value of the AC-predictions. Any errors in the predictions are left to be corrected later when transmission of the AC-differences is completed. Because of these features, NISS's system may introduce large prediction errors in active/complex areas of an image. These errors, in turn, can degrade compression efficiency. Accordingly, it is desirable, and an object of the present invention, to provide a system and method for correcting the artifacts in the intraframe coded frames while achieving substantially improved image quality that would not otherwise be possible at low-bit compression rates. Additionally, and most significantly, it is desirable that this improvement be achieved with no penalty in compression efficiency. The invention solves the problem of correcting "blocking" artifacts that result with intraframe coding, while maintaining image quality and compression efficiency, by appropriately utilizing transform coding techniques.

Following from the above-described prior art, the present invention is directed to improving the results of intraframe coding of electronic images, in the form of motion video sequences or progressive still frames, and particularly, to a system and method for improving image quality in intraframe transform based coding techniques by using prediction of the AC components. The invention involves operating on the AC coefficient prediction, which operation takes place only on the decoder portions of the system in combination with a thresholding technique.

The systems to which the invention is directed essentially operate by subdividing input images into blocks of pixels. These blocks of pixels are changed into blocks of coefficients by a forward transform coding operation,

and the transform coefficients include: DC coefficients, representative of the average value in a block of pixels, and AC coefficients, representative of harmonic frequencies in a block of pixels. The invention recovers a representation of an input image from the transform coefficients by taking the transform coefficients for all of the blocks of the image and beginning by generating predicted values for selected transform coefficients in a given block from the values of its transform coefficients.

- 5 The selected coefficients comprise AC coefficients from the block. After generation the predicted coefficient values of said block are thresholded and the thresholded coefficient values are added to their corresponding transform coefficient values for the given block. These steps are repeated for all of the blocks of the image and the image representation is recovered by applying an inverse transform operation to the results of all of the additions for all of the blocks of the image.

Typically, the transform coefficients for the blocks will be quantized so that the predicted coefficient values are quantized before thresholding, and the results of the additions are dequantized before applying the inverse transform operation. In such event, the quantizing of the predicted coefficient values before thresholding is a finer quantization than that of the transform coefficients of the blocks. Also, scaling of the transform coefficient values of said blocks may be carried out to match the precision of the thresholded coefficient values before the addition step, whereupon compensation for the scaling is performed after applying the inverse transform operation.

Decoder embodiments for both progressive still frame and motion video applications are disclosed.

- 35 Fig. 1a is a block diagram illustrating a progressive still frame DCT encoder in accordance with the prior art.

Fig. 1b is a block diagram as in Fig. 1a illustrating an alternative progressive still frame DCT encoder in accordance with the prior art.

- 40 Fig. 2 is a block diagram illustrating a DCT decoder for use in combination with the DCT encoder shown in Fig. 1a.

Fig. 3 is a block diagram illustrating a typical DCT motion video encoder in accordance with the prior art.

- 50 Fig. 4 is a block diagram illustrating a typical DCT motion video decoder in accordance with the prior art.

- 55 Fig. 5a is a block diagram illustrating a DCT motion video decoder in accordance with the present invention.

Fig. 5b is a block diagram illustrating an alternative embodiment of a DCT decoder in accordance with the present invention. As Fig. 5c is a block diagram illustrating yet another alternative embodiment of a DCT decoder in accordance with the present invention.

Fig. 6a is a block diagram illustrating a DCT progressive still frame encoder in accordance with the present invention.

Fig. 6b is a block diagram illustrating a DCT progressive still frame decoder in accordance with the present invention.

Fig. 7 is a diagrammatic representation in illustration of scaling factors used in connection with the invention.

Fig. 8 is a flowchart illustrating the computation of AC predicted values using a threshold according to the invention.

Fig. 9 is a flowchart illustrating the computation of two threshold values of the threshold of Fig. 8 used in AC prediction.

The present invention involves a system and method for improving the intraframe coding of electronic images including various embodiments respectively capable of treating data representing either motion video sequences or still frames.

Firstly, with regard to the motion video implementation, reference is made to Figs. 3 and 4 which show simplified diagrams of a typical prior art motion video encoder and decoder, respectively, using, e.g., the DCT, although other transforms could be used without loss of generality. The upper path of the encoder of Fig. 3, including transformer 10 and quantizer 20, is the encoder proper and will be referred to as the "transmission encoder".

For intraframe coding, switch S1 in Fig. 3 is in position 1 so that the input image data to the transmission encoder is directly operated upon by the DCT transformer 10, quantized in quantizer 20, and then transmitted. It is noted that the quantized outputs will be typically entropy coded in a coder 50, using Huffman or arithmetic coding techniques, before transmission. However, such additional operations or appropriate extensions, will be chosen by, and within the purview of, those of skill in the art and need not be discussed further here. In the decoder in Fig. 4, switch S2 is also in position 1 allowing the encoded signal to be dequantized (Q^{-1}) in dequantizer 25, and inversely transformed (IDCT) in inverse transformer 11, before being directly output as the reconstructed image, as well as being stored in a Reconstruction frame buffer 60. The output of buffer 60 may be summed with the output of inverse transformer 11 in

a summer 43.

The encoder of Fig. 3 also contains a decoder 70, such as that of Fig. 4, in its feedback loop so that the reconstructed image can be used as a prediction for the next frame by subtracting in a summer 42. Again there may be appropriate extensions to the basic coder/decoder (codec) of Figs. 3 and 4, such as the introduction of motion compensation and filtering of the predicted frame. For interframe coding, switch S1 is in position 2 so that frame difference signals from summer 42, rather than original frame signals on line 14, are transformed and quantized by the DCT transformer 10 and the Q quantizer 20, respectively. Similarly, switch 2 of the decoder is in position 2 so that frame reconstruction is obtained by adding the reconstructed frame differences from summer 43 to the prediction (previous) frame.

As previously noted, at high compression rates, the DCT AC-components are quantized so coarsely that they are simply not detected in smooth areas of an image, thus introducing "blockiness". These artifacts are typical of block-oriented transform techniques and they cannot be easily corrected other than by the use of finer quantizers which increase the transmission bit rate or bandwidth requirements.

Prediction of AC-coefficients is one alternative to be used to correct block artifacts. The scheme shown in Figure 1a cannot be used, however, because it assumes that the AC predictions are quantized Q with the same quantizer 20 as the original AC coefficients. Since this same quantizer was too coarse to avoid the artifacts in the first place, it does not help with the prediction either. It is possible to move the AC quantizer (21 in Fig. 1a) in the system to the position of quantizer 22 shown in Figure 1b; but, in such case, large prediction errors may occur in active/complex areas of the image thus degrading compression efficiency. In either case the complexity of a motion video encoder incorporating the arrangements in Fig. 1a or Fig. 1b in place of the "transmission encoder" of Fig. 3, would be increased significantly, as the prediction circuitry would have to be replicated in the feedback (decoder) path.

Consequently, for intraframe coding in accordance with the present invention, the encoder may be essentially of the form of the "transmission encoder" shown in Fig. 3. However, the feedback decoder 70 will be of a form such as shown in either Fig. 5a, Fig. 5b, or Fig. 5c. It will be seen, therefore, that any increase in complexity in the system is limited to the decoder and accordingly in the encoder to the decoder path. Further, as will be seen below, there will be no degradation in compression efficiency.

Turning to the decoder embodiments shown in Figs. 5a, 5b, and 5c, all will be noted to incorporate the combination of 1) performing an AC prediction on both the DC and AC coefficient inputs, along with 2) a thresholding operation P. More particularly, in the preferred embodiment of Fig. 5a, the DC and AC coefficient inputs, before scale up at 75, are fed over line 91 to AC predictor

32. This predictor may be readily implemented by a combination of simple arithmetic operations, such as that disclosed in the MITCHELL ET AL paper cited above and the use of lookup tables. The prediction coefficients output by predictor 32 are quantized q in a fine quantizer 24, that is, one that produces a quantization q which is finer than the quantization Q of quantizer 20 in Fig. 3. The finely quantized coefficients from fine quantizer 24 are then thresholded P in a suitable threshold 80. Thresholder 80 may be implemented by a lookup table or a comparator, as appropriate for the operating parameters. The thresholded AC coefficients output by thresholder 80 are summed with their corresponding scaled up AC coefficient inputs on line 89 in a summer 44. When switch S3 is in position 1, the output of summer 44 will be sent to the remainder of the decoder which essentially constitutes the components of the decoder of Fig. 4 with the addition of a scale down function at 76, to compensate for the earlier scale up. The scale up function on the AC coefficients in 75 does not necessarily add complexity to the system as there may be a scale up function in the dequantizer 25. The scale down function 76 may also be incorporated in the inverse transformer 11; but, in any event, appropriate scaling in these combinations will be within the purview of those of skill in the art.

The first important feature to be noted in the inventive system, which has implications on implementation complexity, is that AC prediction is done only in the decoder portions. Thus, unlike the prior art, with the invention it is not necessary to transmit the prediction difference, but rather the original AC coefficients themselves are transmitted. Prediction is only used to improve the quality of the decoded image; it has no impact on the coding rate. It has been determined experimentally that with prior art techniques, such as that of NISS, AC prediction has a greater impact on image quality than on compression efficiency. The second important feature is that unlike the decoder shown in Figure 2, a finer quantization, q, is used for the prediction coefficients. In this manner it is possible to predict AC values which could not be detected by the coarse quantization Q. In problem areas, such as flat areas of the image, the AC coefficients tend to be small so that coarse quantization Q will miss them. Thirdly, in accordance with the invention, after mapping the AC predictions through a thresholder operation, P, the predictions are added to a scaled version of the original quantized AC coefficients. It is preferred that q be a linear scaled down version of Q, e.g., q scale down = DC, AC scale up.

With regard to scaling, attention is called to Fig. 7 which diagrams quantization scaling factors, wherein, for instance, a scaling factor of four is shown. It will be seen that $Q_1 = q_1$ and $q_1 = Q/4$. This same scaling factor would be applied to scale up the DC, AC components in Fig 5a. Another important aspect of the invention is the use of thresholder P. Without proper thresholding large errors could be introduced in the AC-prediction es-

timates. The thresholding function P of the invention is used to insure that only AC predictions which could not be detected and quantized Q by the coarse quantizers are allowed, i.e., predicted values which can be detected by the coarse quantizers are simply set to zero. Thus, assuming that the quantizer decision levels are in between the reconstruction levels, and that anything above $Q_1/2$ would be detected by quantizer Q, the mapping generated by P forces $q_1 = 0$ for $q_1 \geq Q_1/2$. This mapping implicitly allows the generation of AC-prediction for smooth areas of the image only. The AC predictions for active areas - where predictions would normally be large - are forced to zero. The smooth areas are thus substantially improved in quality. Since the decoder can calculate the prediction from known information, the improvement in quality comes at NO PENALTY to compression. Experiments show a far superior image quality is obtained when the image is reconstructed in this manner as compared to the use of no AC-prediction.

Another decoder embodiment in accordance with the invention is shown in Fig. 5b, wherein scale up of the DC and AC coefficient inputs is performed at 75' prior to their being fed over respective lines 92 and 93 to AC predictor 32'. The output of predictor 32' is quantized Q in quantizer 24' and thresholded in thresholder 80' before being fed to summer 44. With this arrangement, the scale down function on the AC prediction quantizer 24 of Fig. 5a is not needed in quantizer 24'; however, greater arithmetic precision and larger lookup tables are required for implementing the prediction function in 32'. In this case, the mapping generated by P forces $q_1 = 0$ for $q_1 \geq 2Q_1$.

A further implementation of a decoder in accordance with the invention is shown in Fig. 5c. In this embodiment, inverse quantization Q^{-1} is performed by inverse quantizer 26 on the DC and AC coefficient inputs prior to their being fed over lines 92 and 93 to an AC predictor 32''. With this arrangement, dequantizer 25 and quantizers 24 and 24' of the previous embodiments may be dispensed with; but, a higher precision dequantization Q^{-1} , is needed, and lookup table implementation of the prediction function would require large tables so that the substitution of logical adds and multiplies may be preferred.

While the invention has in the preceding embodiments been described as applied to processing motion video data, the inventive principles disclosed can also be applied to the progressive transmission of still-frame images. In contrast to the AC-prediction performed by the predictor 30 on DC coefficients in the prior art still frame encoder of Fig. 1a, a still frame encoder in accordance with the invention is shown in Fig. 6a, wherein it will be seen that not only the DC-coefficients, but also a portion AC' of the AC-coefficients AC are used for prediction in a predictor 36. Aside from the differences due to the improved AC-prediction function and the addition of a thresholder 81, the other elements of the encoder shown in figure 6a, i.e., quantizer 27, summer 45, etc.,

may be essentially the same as those of the prior art encoder of Fig. 1a.

In the Fig. 6a embodiment, the portion AC' of the AC-coefficients AC constitute those portions of the coefficients that are "coarsely quantized". For example, in an 8-bit sign-magnitude representation of linearly quantized AC coefficients, AC-quantizer levels can be represented as between -127 and +127. AC' could correspond to the most significant bit (MSB) of an AC value, i.e., the first bit after the sign, with the sign bit transmitted only if the value of AC' is non-zero. In such case, AC' can only assume the values of +64, 0, or -64 and can be thought of as a requantization of AC with a linear quantizer step 64 times the original quantizer step. In the preferred embodiment of the invention, the thresholding P of thresholder B1 is controlled by the value of AC' in two different ways. Firstly, if AC'>0, the thresholder forces the prediction to be zero (no prediction).

Secondly, if AC'<0 the thresholder will allow quantized predicted values less than 63; larger values are set to zero. This threshold is chosen because a larger AC value would have been detected by the value of AC' in the first place.

For AC'=0 in successive stages of progression, the difference between the original quantized AC values and their prediction can be transmitted. Since no sign information was transmitted with AC', the sign can be transmitted as soon as the first non-zero magnitude bit of the difference is sent. For AC'>0, the remaining least significant bits (LSB) are simply transmitted.

A progressive still frame decoder according to the invention is shown in Fig. 6b. The received DC and AC' coefficients are fed to an AC predictor 33, quantized in quantizer 28, and thresholded P in thresholder 82, before being summed with Δ AC signals in summer 46. The operation of this decoder reverses the procedure of the encoder in Fig. 6a. If AC'=0, the prediction is zero and AC' is recombinined, through summers 47 and 46, with Δ AC which contains the least significant bits (LSB) information. If AC'>0, the prediction is thresholded before it gets added to the difference data transmitted in later stages of the progression.

It might be noted that in the event that the quantization is not linear in the cited embodiments, the implementation of the invention can be carried out by defining the threshold values differently.

By way of example, flowcharts are shown in Figs. 8 and 9 of software implementations of NISS's AC prediction formulas in combination with a thresholder in accordance with the present invention. The thresholder allows quantized predicted values of -1, 0, and +1 only. Further, the predictor fine quantizer is of the form of that in Fig. 7.

AC_PREDICT. In Fig. 5, five AC coefficients are predicted. COMPUTE_THR calculates THR1 and THR2 for each coefficient. For each coefficient a quantized DC gradient is calculated according to the formulas taken from NISS and MITCHELL ET AL.

$$\text{GRAD}(0,1) = (DC_4 - DC_6)$$

$$\text{GRAD}(1,0) = (DC_2 - DC_8)$$

$$\text{GRAD}(2,0) = (DC_2 + DC_8 - 2 \times DC_5)$$

$$\text{GRAD}(1,1) = (DC_1 + DC_9 - DC_3 - DC_7)$$

$$\text{GRAD}(0,2) = (DC_4 + DC_6 - 2 \times DC_5)$$

Each gradient is compared against the appropriate set of thresholds. If the absolute value of the gradient is greater or equal to THR2 or less than THR1, the prediction is zero. If $|\text{THR1}(i,j)| \leq \text{GRAD}(i,j) < \text{THR2}(i,j)|$ the prediction is 1.

If $-\text{THR1}(i,j) \geq \text{GRAD}(i,j) > -\text{THR2}(i,j)$ the prediction is -1.

Note that the order of the questions is important since it is possible that THR1 and THR2 are equal. Also note that the gradients are obtained by using quantized DC levels. Finally note that the resulting predictions are stored in the same DCT array where AC_DECODE adds its decoded values.

COMPUTE_THR. Fig. 9 illustrates the computing of the thresholds used in AC prediction. A set of two thresholds are computed for each AC coefficient predicted. These thresholds incorporate the dequantization of the DC gradient, $Q_{0,09}$, and the reduction of the AC quantizer step, $Q_{0,09}/4$ (see Fig. 7). The constants $K(i,j)$ are derived from NISS after a scale up of a factor of 2^{12} , so as to permit integer arithmetic. For example, $K(0,1) = 1108x4096$. These formulas require further normalization by $2^6=64$ so that the total normalization becomes $2^6 \cdot 2^{12} = 2^{18}$. The integer values of K are:

$$K(0,1) = 37318$$

$$K(1,0) = 37318$$

$$K(2,0) = 9136$$

$$K(1,1) = 5313$$

$$K(0,2) = 9136$$

DELTA represents the unnormalized contribution of a step of one in the DC gradient to the quantized AC coefficient. THR1 counts the number of DC gradients steps needed to generate a quantized AC prediction of value 1. THR2 counts the number needed to generate a quantized AC prediction of value 2. The initial value of TEM=2¹⁷ is used for rounding.

It will accordingly be seen that a system and method are disclosed for improving image quality in intraframe transform based coding techniques by using prediction of the AC components, which prediction takes place only in the decoder portions of the system and is combined with a thresholding function.

Claims

1. A method for recovering a representation of an input image from transform coefficients for usage in a data compression system wherein input images are subdivided into blocks of pixels and said blocks of pixels are changed into blocks of coefficients by a

forward transform coding operation, said transform coefficients including DC coefficients, representative of the average value in a block of pixels, and AC coefficients, representative of harmonic frequencies in a block of pixels said method comprising the steps of:

a) receiving said transform coefficients for all of said blocks of said image;

b) generating predicted values for selected transform coefficients in a given block from the values of received transform coefficients, wherein said selected coefficients comprise AC coefficients;

c) thresholding said predicted coefficient values of said block;

d) adding received transform coefficient values for said given block to corresponding ones of said thresholded coefficient values from step c);

e) repeating each of steps b) through d) for all of the blocks of said image received; and

f) recovering said image representation by applying an inverse transform operation to the results of the additions of step d) for all of said blocks of said image received.

2. The method of claim 1 wherein said received transform coefficients for all of said blocks have been quantized and comprising the further steps of:

g) quantizing said predicted coefficient values before said thresholding; and

h) dequantizing the results of the additions of step d) before applying said inverse transform operation.

3. The method of claim 2 wherein said quantizing of said predicted coefficient values before said thresholding is a finer quantization than that of said received transform coefficients for all of said blocks.

4. The method of claim 1 further comprising the steps of:

g) scaling said received coefficient values of said blocks to match the precision of the thresholded coefficient values in step c) before the additions in step d); and

h) compensating for the scaling of step g) after applying said inverse transform operation.

5. The method of claim 4 wherein said scaling step g) comprises scaling up said received coefficient values of said blocks before the generating of predicted values for selected transform coefficients from the values of said received transform coefficients.

6. The method of claim 1 wherein said received transform coefficients for all of said blocks have been quantized and comprising the further step of dequantizing said received coefficient values of said blocks before the generating of predicted values for selected transform coefficients from the values of said received transform coefficients.

7. The method of one of claims 1 to 6 incorporated in the decoder feedback loop of a transform based motion video encoder.

8. An apparatus for recovering a representation of an input image from transform coefficients for usage in a data compression system wherein input images are subdivided into blocks of pixels and said blocks of pixels are changed into blocks of coefficients by a forward transform coding operation, said transform coefficients including DC coefficients, representative of the average value in a block of pixels, and AC coefficients, representative of harmonic frequencies in a block of pixels, said apparatus comprising:

a) first means for receiving said transform coefficients for all of said blocks of said image;

b) second means, connected to said first means and responsive to said received transform coefficients, for generating predicted values for selected transform coefficients in a given block from the values of said received transform coefficients, wherein said selected coefficients comprise AC coefficients;

c) third means, connected to said second means, for thresholding said predicted coefficient values of said block generated by said second means;

d) fourth means, connected to said first and third means, for adding received transform coefficient values from said first means and corresponding thresholded coefficient values from said third means;

e) fifth means for repeatedly reactivating said second, third, and fourth means to operate on said transform coefficients of all of the blocks of said image received; and

- f) sixth means, connected to said fourth means, for applying an inverse transform operation to the results of the additions performed by said fourth means on all of said blocks of said image received, to recover said image representation. 5
9. The apparatus of claim 8 wherein said received transform coefficients for all of said blocks have been quantized and further comprising: 10
- g) seventh means, connected to said second means, for quantizing said predicted coefficient values before said thresholding; and
 - h) eighth means, connected to said fourth means, for dequantizing the results of the additions before said sixth means applies said inverse transform operation. 15
10. The apparatus of claim 8 further comprising: 20
- g) seventh means, connected to said first means and said fourth means, for scaling said received coefficient values of said blocks to match the precision of the thresholded coefficient values from said third means before the additions by said fourth means; and 25
 - h) eighth means, connected to said sixth means, for compensating for the scaling of said seventh means after the application of said inverse transform operation. 30
11. The apparatus of claim 8 wherein said received transform coefficients for all of said blocks have been quantized and further comprising seventh means, connected to said first means for dequantizing said received coefficient values of said blocks before said second means generates the predicted values for selected transform coefficients from the values of said received transform coefficients. 35
12. The apparatus of one of claims 8 to 11 further comprising a transform based motion video encoder having a feedback loop and wherein said first through sixth means are incorporated in said encoder in said feedback loop. 45
13. A method for recovering a representation of an input image from a coded transmission for usage in a progressive transmission scheme for still frame images wherein input images are subdivided into blocks of pixels, said blocks of pixels are encoded into blocks of coefficients by transform coding techniques, and said coefficients are quantized and transmitted progressively, and said transmission comprises a first stage wherein the most significant bits of said coefficients in all blocks are sent, followed by successive stages wherein less significant bits of said coefficients are sent, said method comprising the steps of: 50
- a) receiving the first stage quantized coefficient bit values for all of said blocks of said image;
 - b) generating a quantized predicted value for certain coefficient bits in a given block;
 - c) thresholding said predicted coefficient bit values of said block;
 - d) adding the thresholded coefficient bit values from step c) to the corresponding quantized coefficient bit values of said block;
 - e) repeating each of the foregoing steps for all of the blocks of said image received; and
 - f) recovering said image representation by applying an inverse transform operation to the results of the additions of step d) for all of said blocks of said image received.
14. The method of claim 13 further comprising the steps of:
- g) additionally receiving said less significant bit values from said successive stages for all of said blocks of said image; and
 - h) including said less significant bit values from said successive stages for all of said blocks of said image in said addition step d).
- Patentansprüche**
1. Verfahren zur Wiederherstellung einer Darstellung eines Eingangsbildes aus Umwandlungskoeffizienten zur Anwendung in einem Datenkomprimierungssystem, wobei Eingangsbilder in Pixelblöcke unterteilt werden und die Pixelblöcke durch eine Vorwärtsumwandlungs-Codieroperation in Koeffizientenblöcke umgewandelt werden, wobei die Umwandlungskoeffizienten Gleichspannungs-(DC-)Koeffizienten, die den Durchschnittswert in einem Pixelblock darstellen, und Wechselspannungs-(AC-)Koeffizienten, die Harmonische in einem Pixelblock darstellen, einschließen, und wobei das Verfahren die folgenden Schritte umfaßt:
- a) Empfangen der Umwandlungskoeffizienten für alle Blöcke des Bildes;
 - b) Erzeugen von vorausgesagten Werten für ausgewählte Umwandlungskoeffizienten in

- einem bestimmten Block aus den Werten von empfangenen Umwandlungskoeffizienten, wobei die ausgewählten Koeffizienten AC-Koeffizienten einschließen;
- c) Festlegen eines Schwellenwertes für die vorausgesagten Koeffizientenwerte des Blocks,
- d) Addieren von Werten von empfangenen Umwandlungskoeffizienten für den bestimmten Block zu entsprechenden der Koeffizientenwerte vom Schritt c), für die ein Schwellenwert festgelegt worden ist;
- e) Wiederholen eines jeden der Schritte b) bis d) für alle Blöcke des empfangenen Bildes; und
- f) Wiederherstellen der Bilddarstellung durch Anwenden einer Rücktransformationsoperation auf die Ergebnisse der Additionen des Schritts d) für alle Blöcke des empfangenen Bildes.
2. Verfahren nach Anspruch 1, wobei die empfangenen Umwandlungskoeffizienten für alle Blöcke quantisiert worden sind und das Verfahren die folgenden weiteren Schritte umfaßt:
- g) Quantisieren der vorausgesagten Koeffizientenwerte vor der Schwellenwertfestlegung; und
- h) Dequantisieren der Ergebnisse der Additionen des Schritts d) vor dem Anwenden der Rücktransformationsoperation.
3. Verfahren nach Anspruch 2, wobei die Quantisierung der vorausgesagten Koeffizientenwerte vor der Schwellenwertfestlegung eine feinere Quantisierung als die Quantisierung der empfangenen Umwandlungskoeffizienten für alle Blöcke ist.
4. Verfahren nach Anspruch 1, das des weiteren die folgenden Schritte umfaßt:
- g) vor den Additionen im Schritt d) Skalieren der Werte der empfangenen Koeffizienten der Blöcke, damit sie der Genaugkeit der Koeffizientenwerte, für die im Schritt c) ein Schwellenwert festgelegt worden ist, entsprechen; und
- h) nach dem Anwenden der Rücktransformationsoperation Ausgleichen der im Schritt g) vorgenommenen Skalierung.
5. Verfahren nach Anspruch 4, wobei der Skalierungsschritt g) die Aufwärtsskalierung der Werte der empfangenen Koeffizienten der Blöcke vor dem Erzeugen von vorausgesagten Werten für ausgewählte Umwandlungskoeffizienten aus den Werten der empfangenen Umwandlungskoeffizienten einschließt.
6. Verfahren nach Anspruch 1, wobei die empfangenen Umwandlungskoeffizienten für alle Blöcke quantisiert worden sind und das Verfahren den weiteren Schritt der Dequantisierung der Werte der empfangenen Koeffizienten der Blöcke vor dem Erzeugen von vorausgesagten Werten für ausgewählte Umwandlungskoeffizienten aus den Werten der empfangenen Umwandlungskoeffizienten einschließt.
7. Verfahren nach einem der Ansprüche 1 bis 6, das in der Rückkopplungsschleife des Decodierers eines auf einer Umwandlung basierenden Bewegtbild-Codierers enthalten ist.
8. Vorrichtung zur Wiederherstellung einer Darstellung eines Eingangsbildes aus Umwandlungskoeffizienten zur Verwendung in einem Datenkomprimierungssystem, wobei Eingangsbilder in Pixelblöcke unterteilt werden und die Pixelblöcke durch eine Vorwärtsumwandlungs-Coderoperation in Koeffizientenblöcke umgewandelt werden, wobei die Umwandlungskoeffizienten DC-Koeffizienten, die den Durchschnittswert in einem Pixelblock darstellen, und AC-Koeffizienten, die Harmonische in einem Pixelblock darstellen, einschließen, und wobei die Vorrichtung folgendes umfaßt:
- a) ein erstes Mittel, um die Umwandlungskoeffizienten für alle Blöcke des Bildes zu empfangen;
- b) ein zweites Mittel, das mit dem ersten Mittel verbunden ist und auf die empfangenen Umwandlungskoeffizienten anspricht, um vorausgesagte Werte für ausgewählte Umwandlungskoeffizienten in einem bestimmten Block aus den Werten der empfangenen Umwandlungskoeffizienten zu erzeugen, wobei die ausgewählten Koeffizienten AC-Koeffizienten einschließen;
- c) ein drittes Mittel, das mit dem zweiten Mittel verbunden ist, um für die vorausgesagten Koeffizientenwerte des Blocks, die von dem zweiten Mittel erzeugt worden sind, einen Schwellenwert festzulegen;
- d) ein vierter Mittel, das mit dem ersten Mittel und mit dem dritten Mittel verbunden ist, um Werte von empfangenen Umwandlungskoeffizienten von dem ersten Mittel und entsprechende Koeffizientenwerte von dem dritten Mit-

- tel, für die ein Schwellenwert festgelegt worden ist, zu addieren
- e) ein fünftes Mittel zur wiederholten Reaktivierung des zweiten, des dritten und des vierten Mittels, um Operationen an den Umwandlungskoeffizienten von allen Blöcken des empfangenen Bildes auszuführen; und
- f) ein sechstes Mittel, das mit dem vierten Mittel verbunden ist, um eine Rücktransformationsoperation auf die Ergebnisse der Additionen anzuwenden, die von dem vierten Mittel an allen Blöcken des empfangenen Bildes durchgeführt wurden, um die Bilddarstellung wiederherzustellen.
9. Vorrichtung nach Anspruch 8, wobei die empfangenen Umwandlungskoeffizienten für alle Blöcke quantisiert worden sind und das Verfahren des weiteren folgendes umfaßt:
- g) ein siebtes Mittel, das mit dem zweiten Mittel verbunden ist, um die vorausgesagten Koeffizientenwerte vor der Schwellenwertfestlegung zu quantisieren; und
- h) ein achtes Mittel, das mit dem vierten Mittel verbunden ist, um die Ergebnisse der Additionen zu dequantifizieren, bevor das sechste Mittel die Rücktransformationsoperation anwendet
10. Vorrichtung nach Anspruch 8, die desweiteren folgendes umfaßt:
- g) ein siebtes Mittel, das mit dem ersten Mittel und mit dem vierten Mittel verbunden ist, um die Werte der empfangenen Koeffizienten der Blöcke zu skalieren, damit sie der Genauigkeit der Koeffizientenwerte von dem dritten Mittel, für die ein Schwellenwert festgelegt worden ist, vor den von dem vierten Mittel durchgeführten Additionen entsprechen; und
- h) ein achtes Mittel, das mit dem sechsten Mittel verbunden ist, um die von dem siebten Mittel vorgenommene Skalierung nach dem Anwenden der Rücktransformationsoperation auszugleichen
11. Vorrichtung nach Anspruch 8, wobei die empfangenen Umwandlungskoeffizienten für alle Blöcke quantisiert worden sind und die Vorrichtung des weiteren ein siebtes Mittel umfaßt, das mit dem ersten Mittel verbunden ist, um die Werte der empfangenen Koeffizienten der Blöcke zu dequantifizieren, bevor das zweite Mittel die vorausgesagten Werte für ausgewählte Umwandlungskoeffizienten aus den Werten der empfangenen Umwandlungskoeffizienten erzeugt
- 5 12. Vorrichtung nach einem der Ansprüche 8 bis 11, die desweiteren einen auf einer Umwandlung basierenden Bewegtbild-Codierer mit Rückkopplungsschleife enthält und wobei das erste bis sechste Mittel in der Rückkopplungsschleife des Codierers enthalten sind
- 10 13. Verfahren zur Wiederherstellung einer Darstellung eines Eingangsbildes aus einer codierten Übertragung zur Anwendung in einem schrittweisen Übertragungsschema für Standbilder, wobei Eingangsbilder in Pixelblöcke unterteilt werden, die Pixelblöcke mittels Umwandlungs-Codierungsverfahren in Koeffizientenblöcke umgewandelt werden und die Koeffizienten quantisiert und schriftweise übertragen werden und die Übertragung eine erste Stufe umfaßt, in der die höchstwertigen Bits der Koeffizienten in allen Blöcken gesendet werden, gefolgt von aufeinanderfolgenden Stufen, in denen niedrigerwertige Bits der Koeffizienten gesendet werden, wobei das Verfahren die folgenden Schritte umfaßt:
- a) Empfangen der quantisierten Koeffizientenbitwerte der ersten Stufe für alle Blöcke des Bildes;
 - b) Erzeugen eines quantisierten, vorausgesagten Wertes für bestimmte Koeffizientenbits in einem bestimmten Block;
 - c) Bestimmen des Schwellenwerts für die vorausgesagten Koeffizientenbitwerte des Blocks;
 - d) Addieren der Koeffizientenbitwerte vom Schritt c), für die ein Schwellenwert festgelegt worden ist, zu den entsprechenden quantisierten Koeffizientenbitwerten des Blocks;
 - e) Wiederholen eines jeden der vorhergehenden Schritte für alle Blöcke des empfangenen Bildes; und
 - f) Wiederherstellen der Bilddarstellung durch Anwenden einer Rücktransformationsoperation auf die Ergebnisse der Additionen des Schritts d) für alle Blöcke des empfangenen Bildes.
14. Verfahren nach Anspruch 13, das desweiteren die folgenden Schritte umfaßt
- g) zusätzliches Empfangen der Werte der niedrigerwertigeren Bits von den aufeinanderfolgen-

den Stufen für alle Blöcke des Bildes; und

h) Einschließen der Werte der niedrigerwertigen Bits von den aufeinanderfolgenden Stufen für alle Blöcke des Bildes im Additionsschritt d).

Revendications

- Procédé pour retrouver, à partir de coefficients de transformation, la représentation d'une image entrée, à utiliser dans un système de compression des données dans lequel les images entrées sont subdivisées en blocs de pixels et les dits blocs de pixels sont changés en blocs de coefficients par une opération directe de codage par transformation, les dits coefficients de transformation incluant des coefficients DC, représentatifs de la valeur moyenne à l'intérieur d'un bloc de pixels, et de coefficients AC, représentatifs des fréquences harmoniques dans un bloc de pixels, le dit procédé comprenant les étapes suivantes :

a) recevoir les dits coefficients de transformation pour l'ensemble des dits blocs de la dite image ;

b) générer les valeurs prévues pour des coefficients de transformation sélectionnés dans un bloc donné, à partir des valeurs de coefficients de transformation reçus, où les dits coefficients sélectionnés comprennent les coefficients AC ;

c) effectuer le seuillage des dites valeurs prédictes des coefficients du dit bloc ;

d) ajouter les valeurs reçues des coefficients de transformation pour le dit bloc donné et certaines valeurs correspondantes des dites valeurs seuils des coefficients obtenues à l'étape c) ;

e) répéter chacune des étapes b) à d) pour l'ensemble des blocs de la dite image reçue; et

f) retrouver la représentation de la dite image en appliquant une opération de transformation inverse aux résultats des additions de l'étape d) pour l'ensemble des dits blocs de la dite image reçue.

- Procédé tel que revendiqué dans la revendication 1, dans lequel les dits coefficients de transformation reçus pour l'ensemble des dits blocs ont été quantifiés, et comprenant en outre les étapes suivantes :

g) quantifier les dites valeurs prédictes des coefficients avant d'effectuer le dit seuillage ; et

h) "déquantifier" les résultats des additions de l'étape d) avant d'appliquer la dite opération de transformation inverse.

- Procédé tel que revendiqué dans la revendication 2, dans lequel la dite quantification des dites valeurs prédictes des coefficients, avant le dit seuillage, est une quantification plus fine que celle des dits coefficients de transformation reçus pour l'ensemble des dits blocs.
- Procédé tel que revendiqué dans la revendication 1 comprenant en outre les étapes suivantes:
 - cadrer les dites valeurs reçues des coefficients des dits blocs afin d'obtenir une précision correspondant à celle des valeurs seuils des coefficients dans l'étape c) avant les additions de l'étape d) ; et
 - compenser le cadrage de l'étape g), après l'application de la dite opération de transformation inverse.
- Procédé tel que revendiqué dans la revendication 4, dans lequel la dite étape de cadrage g) comprend l'amplification des dites valeurs reçues des coefficients des dits blocs, avant de générer des valeurs prédictes pour les coefficients de transformation sélectionnés à partir des valeurs des dits coefficients de transformation reçus.
- Procédé tel que revendiqué dans la revendication 1, dans lequel les dits coefficients de transformation reçus pour l'ensemble des dits blocs ont été quantifiés et, comprenant l'étape supplémentaire consistant à déquantifier les dites valeurs reçues des coefficients des dits blocs avant de générer des valeurs prédictes pour des coefficients de transformation sélectionnés, à partir des valeurs des dits coefficients de transformation reçus.
- Procédé tel que revendiqué dans l'une des revendications 1 à 6, incorporé dans la boucle de rétroaction de décodage d'un codeur vidéo basé sur la transformation
- Appareil pour retrouver une représentation d'une image entrée, à partir de coefficients de transformation, à utiliser dans un système de compression des données dans lequel les images entrées sont subdivisées en blocs de pixels et les dits blocs de pixels sont changés en blocs de coefficients par une opération de codage par transformation directe, les dits coefficients de transformation incluant des coefficients DC, représentatifs de la valeur moyenne à l'intérieur d'un bloc de pixels, et des coefficients AC, représentatifs des fréquences harmoniques dans

un bloc de pixels, le dit appareil comprenant :

a) un premier dispositif pour recevoir les dits coefficients de transformation pour l'ensemble des dits blocs de la dite image ;

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b) un second dispositif, connecté au dit premier dispositif et sensible aux dits coefficients de transformation reçus, pour générer des valeurs prédictes pour des coefficients de transformation sélectionnés dans un bloc donné, à partir des valeurs des dits coefficients de transformation reçus, où les dits coefficients sélectionnés comprennent les coefficients AC ;

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c) un troisième dispositif, connecté au dit second dispositif, pour effectuer le seuillage des dites valeurs prédictes des coefficients du dit bloc générées par le dit second dispositif ;

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d) un quatrième dispositif, connecté aux dits premier et troisième dispositifs, pour additionner les valeurs reçues des coefficients de transformation provenant du dit premier dispositif et les valeurs seuils correspondantes des coefficients provenant du dit troisième dispositif,

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e) un cinquième dispositif pour réactiver sans cesse les dits second, troisième et quatrième dispositifs pour qu'ils opèrent sur les dits coefficients de transformation de l'ensemble des blocs de la dite image reçue ; et

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f) un sixième dispositif, connecté au dit quatrième dispositif, pour appliquer une opération de transformation inverse aux résultats des additions effectuées par le dit quatrième dispositif sur l'ensemble desdits blocs de ladite image reçue, pour retrouver la représentation de ladite image.

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9. Appareil selon la revendication 8 dans lequel lesdits coefficients de transformation reçus pour tous lesdits blocs sont quantifiés et ledit appareil comportant en outre :

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g) un septième dispositif, connecté audit second dispositif, pour quantifier lesdites valeurs de coefficients prédictes avant, ledit seuillage et

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h) un huitième dispositif, connecté audit quatrième dispositif pour déquantifier les résultats des additions avant que ledit sixième dispositif n'applique ladite opération de transformation inverse

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10. Appareil selon la revendication 8 comportant en

autre :

g) un septième dispositif, connecté auxdits premier et quatrième dispositifs, pour effectuer le codage desdites valeurs de coefficients reçues desdits blocs afin d'atteindre la précision des valeurs de coefficients seuillées issues dudit troisième dispositif avant les opérations d'addition par ledit quatrième dispositif et

h) un huitième dispositif, connecté audit sixième dispositif, pour compenser le codage par ledit septième dispositif après l'application de ladite opération de transformation inverse.

11. Appareil selon la revendication 8 dans lequel lesdits coefficients de transformation reçus, pour tous les blocs, sont quantifiés et ledit appareil comportant en outre un septième dispositif, connecté audit premier dispositif pour déquantifier lesdites valeurs de coefficients reçues desdits blocs avant que ledit deuxième dispositif n'engendre les valeurs prédictes pour des coefficients de transformation choisies à partir des valeurs des coefficients de transformation reçus.

12. Appareil selon l'une des revendications 8 à 11 comportant en outre un dispositif de codage vidéo de mouvement basé sur une transformation comportant une boucle de réaction et dans lequel lesdits premier au sixième dispositifs sont incorporés audit dispositif de codage dans ladite boucle de réaction.

13. Procédé pour retrouver la représentation d'un image d'entrée à partir d'une transmission codée, pour utilisation dans un arrangement de transmission progressive pour des images de trame fixes, dans lequel les images d'entrée sont subdivisées en blocs de pixels, lesdits blocs de pixels étant changés en blocs de coefficients par des techniques de codage par transformation et lesdits coefficients étant quantifiés et transmis progressivement, ladite transformation comprenant une première phase au cours de laquelle les bits les plus significatifs des coefficients, dans tous les blocs, sont envoyés, ladite phase étant suivie par des phases successives au cours desquelles les bits les moins significatifs desdits coefficients sont envoyés, ledit procédé comprenant les étapes qui consistent à :

a) recevoir les valeurs des bits des coefficients quantifiés au cours de ladite première phase pour tous les blocs de ladite image ;

b) générer une valeur prédicté quantifiée pour certains bits de coefficients dans un bloc

donné ;

c) effectuer le seuillage desdites valeurs prédictes des bits de coefficients dudit bloc ;

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d) additionner les valeurs des bits de coefficients seuillés obtenues à l'étape c avec les valeurs de bit de coefficients quantifiées correspondantes dudit bloc ;

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e) répéter chacune des étapes précédentes pour tous les blocs de l'image reçue et,

f) retrouver la représentation de ladite image en appliquant l'opération de transformation inverse aux résultats des additions de l'étape d pour tous les blocs de l'image reçus

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14. Procédé selon la revendication 13 comprenant en outre les étapes qui consistent à:

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g) recevoir additionnellement les valeurs desdits bits les moins significatifs issues desdites phases successives, pour tous les blocs de ladite image et,

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h) inclure lesdites valeurs desdits bits les moins significatifs issues desdites phases successives pour tous les blocs de ladite image, dans ladite étape d'addition d).

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FIG. 1a PRIOR ART

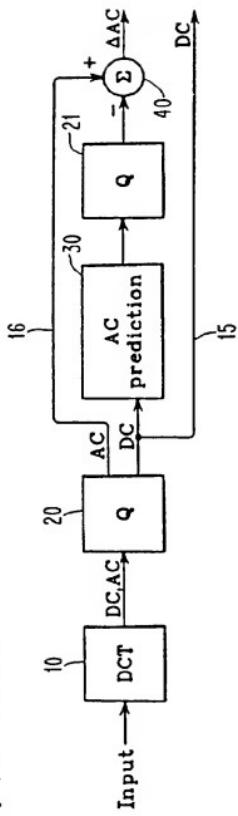


FIG. 1b PRIOR ART

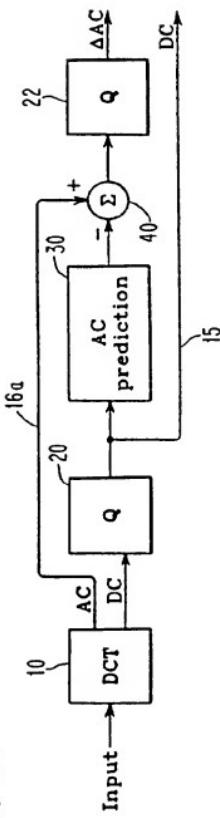


FIG. 2 PRIOR ART

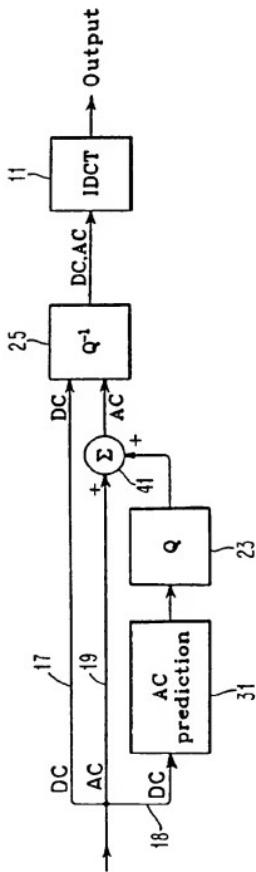


FIG. 3 PRIOR ART

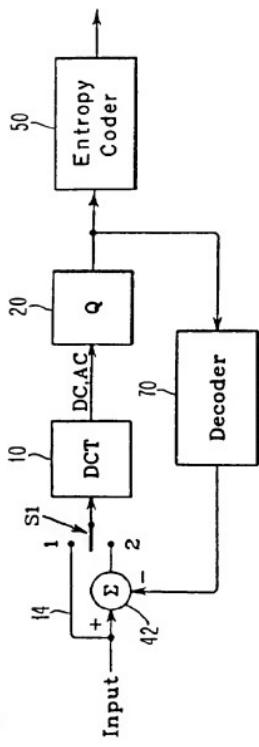


FIG. 4 PRIOR ART

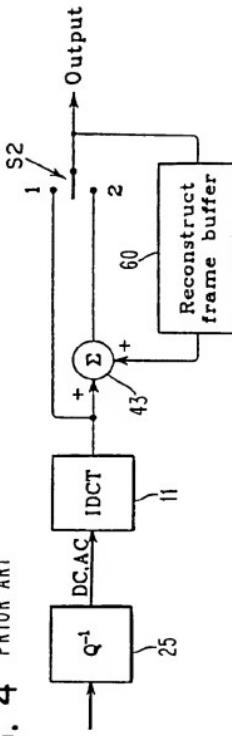


FIG. 5a

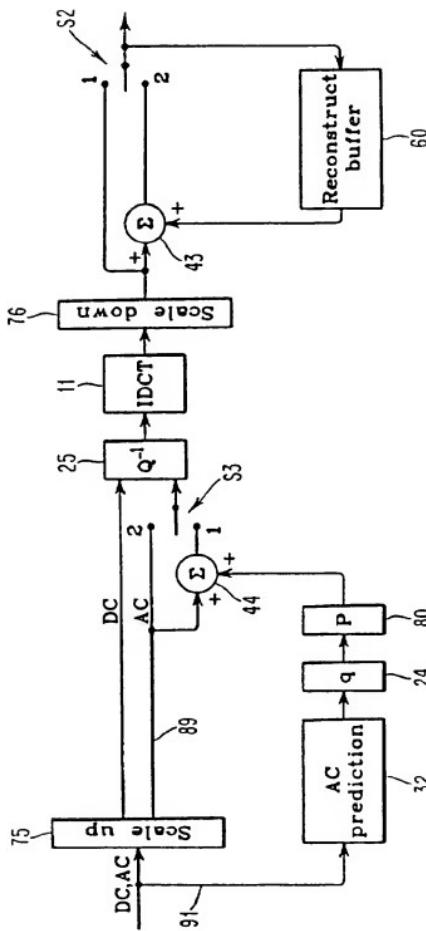


FIG. 5b

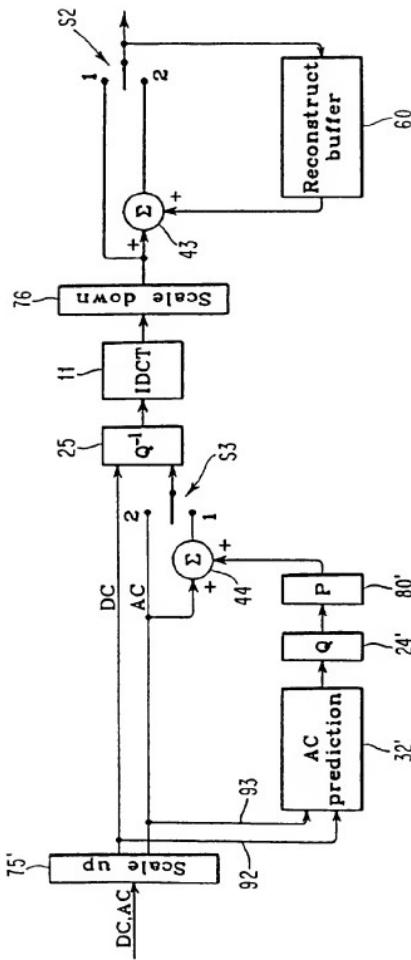


FIG. 5c

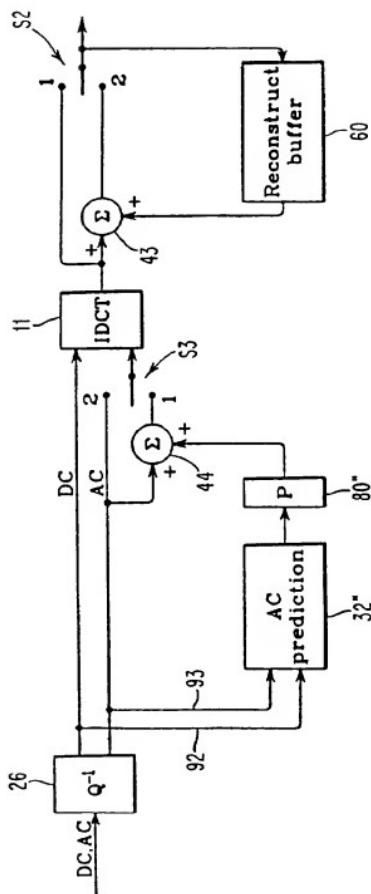


FIG. 6a

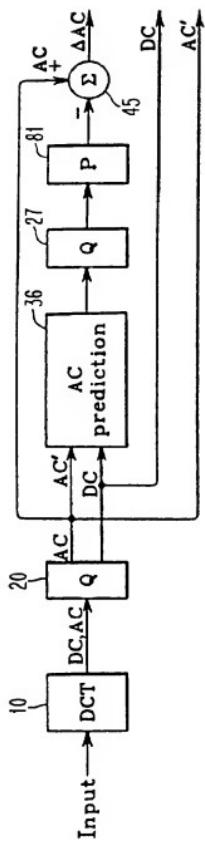


FIG. 6b

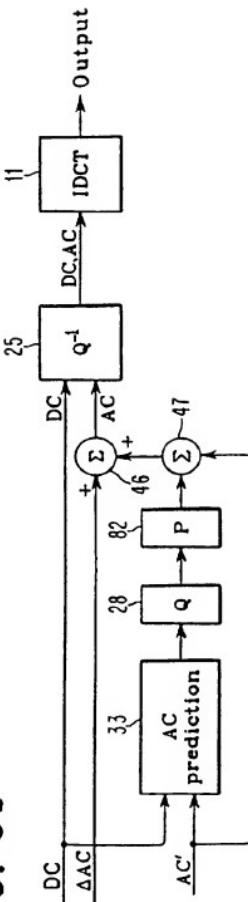


FIG. 7

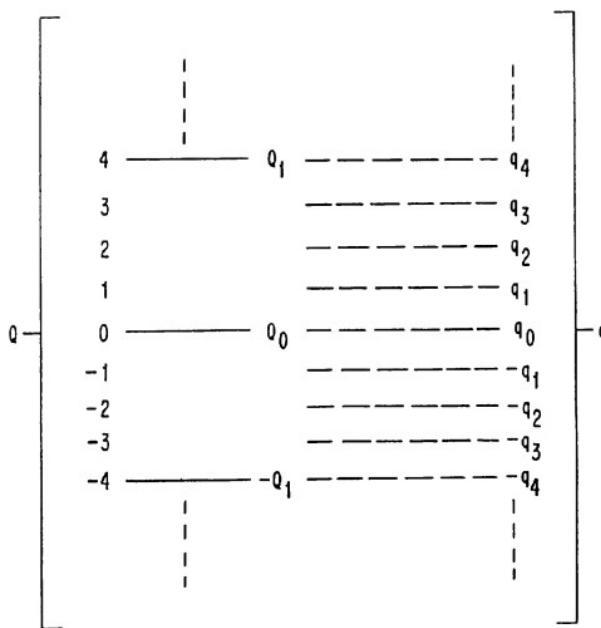


FIG. 8

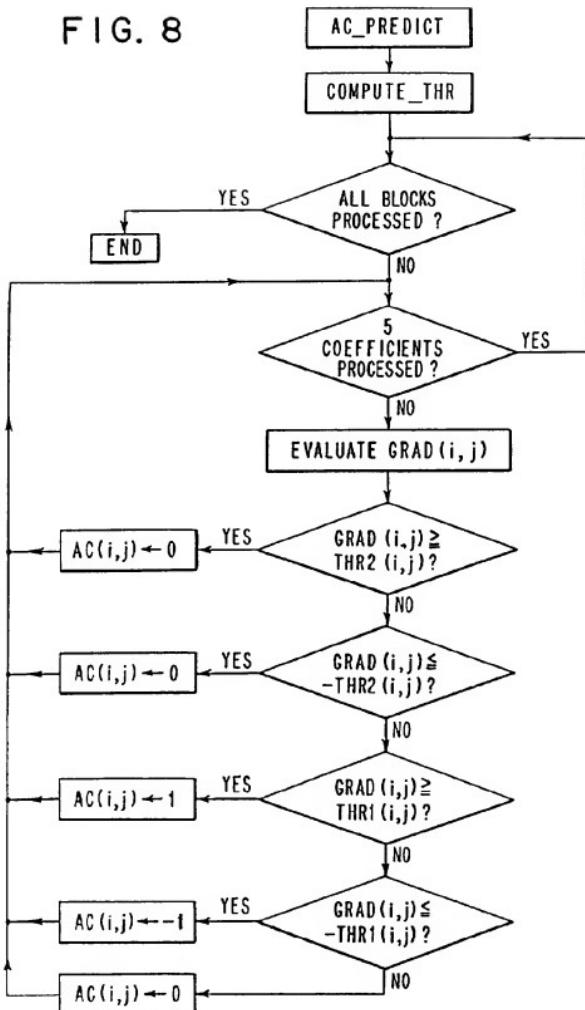


FIG. 9

